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Integral Estimators of Radionuclide Production in Soil

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An important application of hadronic cascade calculations is to estimate activation of soil near points where significant beam losses occur. Specifically the problem is to calculate the production of one or more radionuclides in a large region of space occupied by soil which (typically) surrounds a target-in-a-cave geometry. The spatial distribution of the radionuclides produced within the region is often of lesser interest.

The usual calculational approach at Fermilab uses the Monte-Carlo program CASIM[1] coded for the specific geometry of the problem and integrates the resulting spatial distribution of the star density over a sufficiently large region of the soil. The total star production thus obtained can be simply related to the radioactivation problem.[2]

If indeed the spatial variation of the star (or radionuclide) production is of no interest then the use of an integral estimator has clear advantages. This estimator is a measure of the average total number of stars (or radionuclides) produced by a particle introduced in an infinite medium of soil including stars produced by all descendants of the particle. The total star production in a finite region of space is then the sum of the integral estimators of all particles entering minus that of all particles leaving the region. The latter can actually be neglected in most applications. The advantage of this procedure over the differential mode is twofold (a) generally speaking the integral estimator is a better measure of total star production since it derives from an average over many cascades, (b) if indeed the debit due to particles leaving the soil can be neglected then the cascades need not be traced through the soil which saves computer time. The price that is paid here or in any other problem which could benefit from the introduction of integral estimators is the effort to compute such estimators and this must be weighed against the resulting savings in future applications.

Fig. 1 presents the integral estimator for star production in soil due to particles above a lower momentum limit of 0.3 GeV/c. Negative pions at rest have a large probability for nuclear capture with subsequent emission of fast nucleons.

A crude guess of 0.5 stars produced by such zero momentum pions (mainly via fast neutrons) has been included in Fig. 1.

Fig. 2 shows the integral estimator of Na^{22} production in Fermilab soil. It is based on an earlier compilation of the macroscopic cross section.[3] Similar to star production the estimator for zero momemtum pions has been crudely valued at 0.022 Na^{22} atoms. An estimator for H^3 production also has important applications. It is not included in the present note because its macroscopic cross section in soil is not readily available.

The estimators may also serve as upper limits of soil activation outside the realm of Monte Carlo calculations. A version of CASIM specifically modified for use with the integral estimators is available.

REFERENCES

1. A. Van Ginneken, "CASIM. Program to Simulate Hadronic Cascades in Bulk Matter", Fermilab FN-272 (Jan., 1975).

2. M. Awschalom, "Calculation of the Radionuclide Production in the Surroundings of the NAL Neutrino Laboratory", Fermilab TM-292-A (March, 1971).

3. A. Van Ginneken, "Na^{22} Production Cross Section in Soil", Fermilab TM-283 (Jan., 1971).

FIGURE CAPTIONS

Fig. 1. Integral estimators for star production in soil due to particles with momenta above 0.3 GeV/c.

Fig. 2. Integral estimators for Na^{22} production in Fermilab soil.

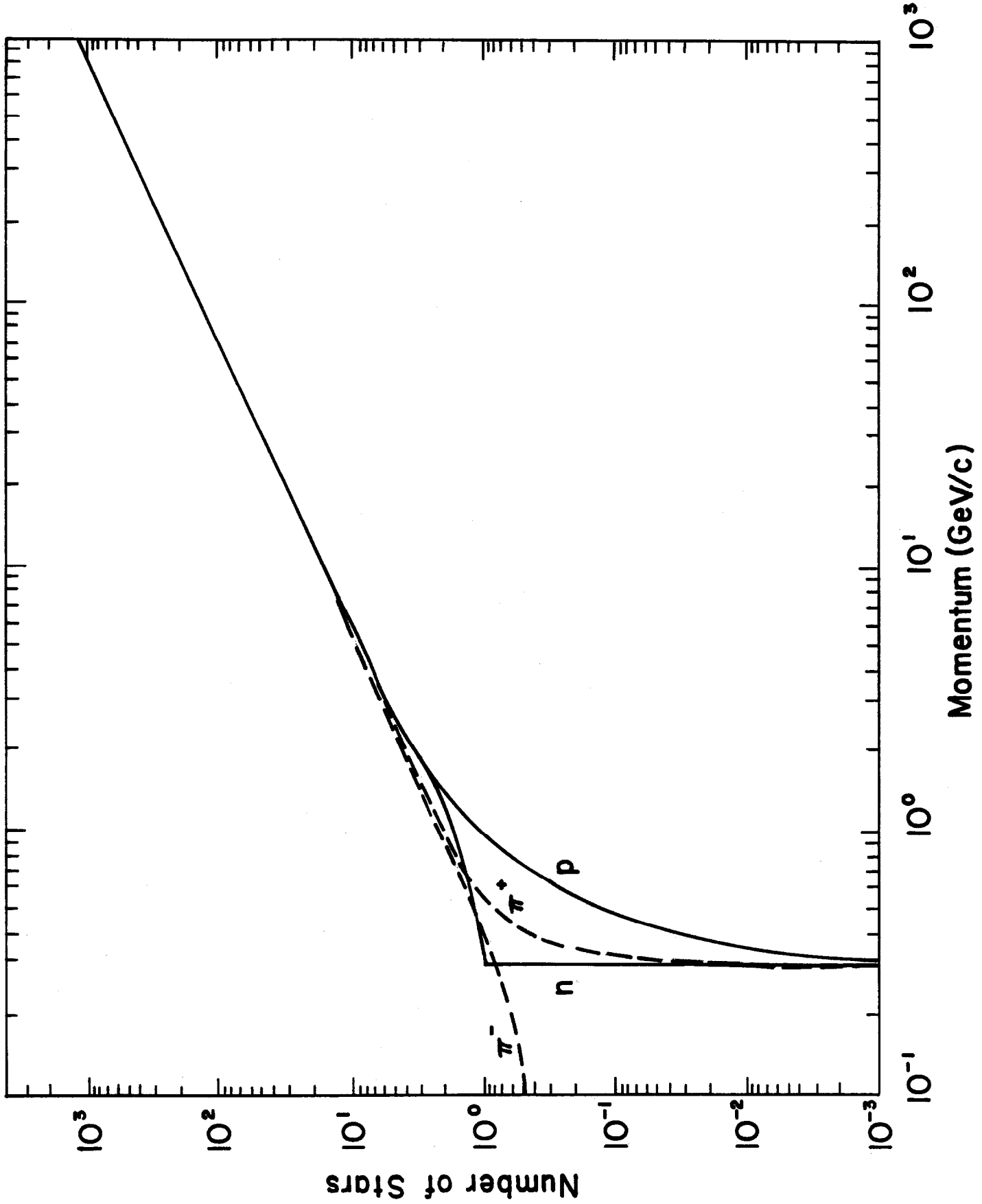
Number of Stars
Momentum (GeV/c)
p
π^+
n
π^-
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}

Fig. 1

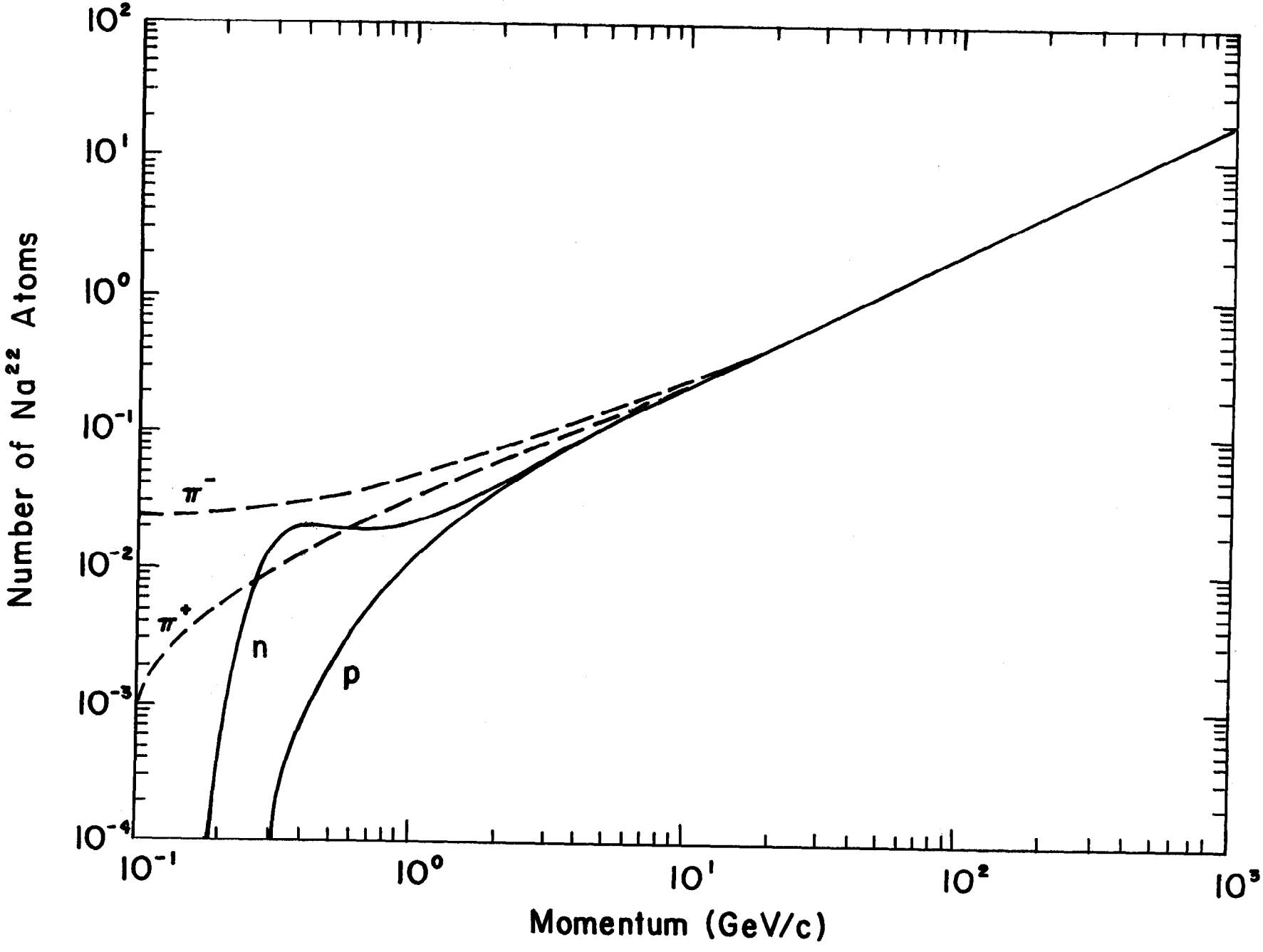

Fig. 2

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